Australian Journal of Ophthalmology 1983; **11:** 295-301

EVOKED RESPONSES TO DISTINCT AND NEBULOUS STEREOSCOPIC STIMULI

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Abstract

When geometric or contoured shapes are generated as disparity regions in dynamic random-dot stereograms, the question of whether the subject's response is evoked largely by boundaries and corners of the disparate region arises. To examine this question a disparate square was shifted randomly within a focal region at one millisecond intervals, resulting in a nebulous stimulus which "welled up" in the centre of the field of view. The technique may be regarded as an analogue of the defocusing technique used to resolve similar questions about evoked potentials to patterned stimuli.

Average visual evoked potentials (VEP) were recorded from homolateral pairs of occipital and posterior temporal electrodes referred to a common midline prefrontal site. The latencies and amplitudes of VEP to distinct and nebulous stimuli were compared in a group of young normal adults, of whom 14 succeeded in perceiving and 14 failed to perceive the presented stimuli.

Latencies of maximal response to distinct and nebulous stimuli were closely similar in the two groups (range N242-N252). Mean amplitudes of the peak response differed between perceivers and non-perceivers. The responses to nebulous stimuli were smaller than those to distinct stimuli in site-for-site comparisons in both groups. Even in short averaging runs a substantial VEP (about 3 microvolt) was recorded to nebulous stimuli in the perceiver group.

It is suggested that both disparity and boundary features contribute to the VEP when this particular display system is used.

It is known that visual evoked potentials are enhanced in amplitude by spatial structure within the stimulus fields[1] and that in patterned stimuli corners evoke larger potentials than stripes.[2] The disparities generated in random-dot stereograms are often programmed as geometric shapes with sharp edge details.[3,4] In order to delineate the stereoscopic visual evoked potential (SVEP) more completely it is important to assess the differential contribution of edge features and the disparity-as-such to the magnitude and latency of the response. The practical difficulty is to produce an "edgeless" disparity to set alongside the standard "edged" stimulus. The strategy devised by a member of our research team (R.A. Neill) was to shift the disparate square randomly

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TABLE 1
Group Composition

Group	Number of subjects		Age range (years)	Mean age (years)	Handedness	
	Male	Female			Right	Left
P	4	10	20-33	23.1 (4.65)	12	2
N	2	12	20-40	22.1 (5.18)	12	2

P = Perceiver, N = Non-perceiver; Standard deviation in parentheses.

at one millisecond intervals within a focal region, thereby preserving the basic properties of form and area of the stimulus and thus its comparability with the standard distinct square shape. The resulting disparity was of nebulous shape, difficult for the observer to describe, sometimes referred to as squarish, sometimes circular, sometimes merely geometric. The technique may be regarded as an analogue of stimulus defocusing, which is used to assess the influence of contours on evoked potentials to patterned or complex natural stimuli.

The hypothesis was that amplitude of the SVEP would be greater to the edged than to the edgeless stimuli. Previous experience had shown that a proportion of binocular subjects is unable to perceive the briefly presented random-dot stimuli, yet SVEP is measurable in some of these non-perceivers. It was therefore anticipated that failure to perceive the distinct stimulus would extend in the individual subject to the nebulous stimulus and that SVEP amplitude of perceivers (P) would exceed that of non-perceivers (N).

MATERIALS AND METHODS

Subjects

Third year psychology students ($n = 28$) undertaking a course in electrophysiological techniques served as subjects. Equal numbers of subjects were classified perceivers (P) or non-perceivers (N). Group composition is shown in Table 1.

Apparatus and Procedure

The electronics of the random-dot generator and the optics of the dynamic display system have been described elsewhere.[4-6]

Form of disparity, distinct or nebulous, was varied by teleprinter command. Control of response acquisition and storage on magnetic tape were exerted through the laboratory minicomputer.

The laboratory was darkened during each experimental run. The subject's description of the stimulus was recorded at the termination of each series of trials. A disparate square (30 arc minutes, crossed), subtending 3° (30 minutes of arc) was presented in each series of trials for a duration of 100 milliseconds, with 1930 milliseconds interstimulus interval.

Scalp sites 0_1, 0_2, T_5, T_6 (10-20 system) were referenced to a common midline site 10 cm posterior to the nasion. Eye movement was monitored bipolarly through electrodes placed obliquely across the left eye. Filter settings were in the range 0.53-30 Hz (3 dB down). A standard preliminary procedure of normalising input and equalising across all channels in relation to the calibration signal was employed. Visual evoked potentials to the stereographic stimuli were averaged on-line and analysed in off-line processing. Monocular recording (one lens occluded) preceded binocular trials. The EEG was monitored for alertness in several intervals during the experiment.

In accordance with the previously expressed aim of the authors to derive an objective result in the minimum number of test trials, the various tests, with one exception (the final test presenting edged stimuli, where number of trials was 32) were limited to eight trials. The averaged SVEP constitute the prime data.

Visual Screening Tests

Preliminary tests of acuity, ocular balance and stereopsis were carried out on all subjects. On completion of the SVEP experiment a final

behavioural assessment of stereopsis was carried out using the Randot Stereo Tests (Stereo Optical Co., Chicago).

Results of the visual screening tests are summarised below.

P group: The subject inferior to 6/6 binocular acuity or 6/6-2 monocular; group mean result on Stereo Wedge test[7], of 140 seconds of arc, all subjects achieving criterion for useful stereoscopic vision; monocular minus binocular results indicate useful stereopsis in 12 subjects; group mean ocular deviation $-0.86°$; no convergent subjects; mean error Clement-Clarke "stereo number" slides 0.64; mean Randot test result 31 seconds of arc.

N group: One subject 6/6-2 binocular, 6/9-3 right monocular, no other subject inferior to 6/5-1 binocular; group mean Stereo Wedge result of 245 seconds of arc, three subjects with questionable binocular advantage though each achieved 200 seconds of arc in a single binocular trial; on minimum binocular result, two subjects had questionable binocular advantage; mean ocular deviation $-0.39°$, four subjects convergent; mean error Clement-Clarke slides 0.86; mean Randot result 53 seconds of arc.

The N group is thus somewhat inferior to the P group in general results on the stereo tests.

RESULTS

Data were collected for the individual subjects as averages of responses to centre-field stimuli, as in Table 2.

TABLE 2
Data Collection

Number of trials	Viewing condition	Stimulus type
8	Monocular	Edged
8	Binocular	Edged
8	Binocular	Edgeless
32	Binocular	Edged

The average response waveforms were submitted to several different measurement procedures. An automatic window-sampling program extracted the average response over the set interval as well as summating the activity over each data point in the interval and writing out the integral. These data were secured for each of the conditions tabulated above. In addition a cursor program was employed to determine the main peak latency and to refine peak amplitude measurement. The latter step was judged necessary when inspection of the waveforms revealed that the baseline set by the normalising procedure (the average of EEG in the period 500 milliseconds prior to the trigger which initiated the averaging epoch for each trial) in many of the subjects was apparently responsive to the regularity of the interstimulus interval. The corrective procedure which was employed involved, first, averaging the response in the window 89-221 milliseconds after the beginning of the epoch relative to the initially established baseline. Secondly, this value, converted to ordinates (multiplied by four to allow for the gain setting and the voltage of the calibration input) was subtracted from the cursor-determined ordinate value for the peak amplitude within the interval 180-310 milliseconds. This response interval was chosen as optimal in width through rigorous examination of superaverage (group averages) and individual subject waveforms. The effect of this secondary procedure then was to normalise the response in an individual manner for each subject. In the opinion of the authors this method of response measurement is more objective and valid than the usual methods employed, but it is tedious.

A further procedure was tried to offset the possible influence of intrinsic EEG activity on the peak response measure. For a single site (O_2) the monocular data were submitted to the identical special normalisation procedures described above and the maximum amplitude of the monocular curve was calculated in the selected response interval. These values were correlated with the corrected O_2 amplitudes for the binocular condition. In the N group, $r=+0.17$ which is not significant; in the P group the two measures correlated inversely, but significantly; $r=-0.77$, $df=12$, $P<0.01$. Thus

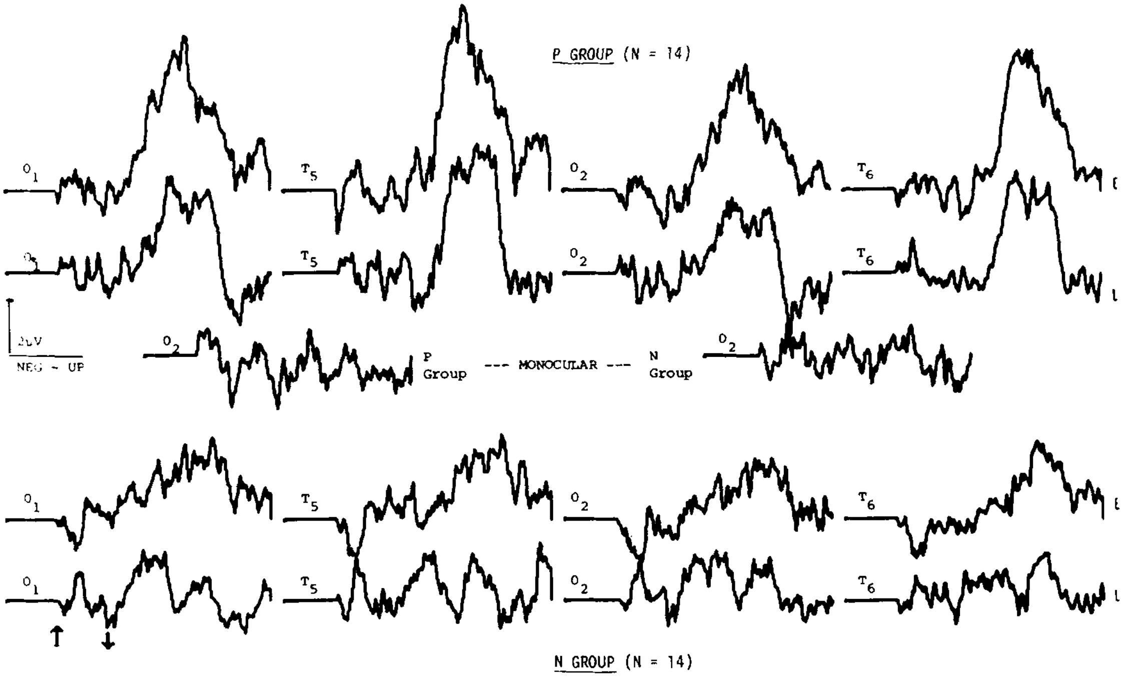

Figure 1: Group superaverages of responses to random-dot stimuli. Each trace represents 512 milliseconds, stimulus on ↑ 100 msec, off ↓ 200 msec, 8-trial averages each subject. E = Edged stimuli; L = Edgeless stimuli.

in this group one might argue that the amplitude of "spontaneous" activity influences the amplitude of the SVEP, albeit negatively. To check the possible effect, the corrected monocular O_2 amplitude was subtracted from the corrected binocular O_2 amplitude; the new binocular values were then correlated with the old. A high rank order correspondence was shown ($r = +0.897$, $df = 26$, $P < 0.001$). This was interpreted as indicating that this final step in transformation of the response measure was unnecessary. The renormalised data were therefore used and the statistics for these data are presented in Table 3 and Figures 1 and 2, as illustrative of the general outcome for the several amplitude measures.

Figure 1 shows the plots of the group superaverages, the SVEP peak showing up most prominently as a slow late negative wave in the P group at all sites, maximally at T_5. The poorest group averages are those of the N group for the edgeless stimulus condition.

Table 3 contains the means and dispersion measures for the SVEP peak amplitudes (corrected as described above). It should be noted that there is a wide range of response among the individual subjects, as illustrated by the following results for the T_5 site. In the P group the range is from -15.25 to -3.1 microvolts for the edged stimulus, and from -10.25 to -1.05 for the edgeless stimulus; in the N group the ranges are -6.10 to $+0.41$ (edged) and -6.70 to $+1.30$ (edgeless).

Statistical Analysis: Amplitudes

The peak amplitude and integrals data were submitted to analyses of variance (BMDP-2V program). The results are similar for all the analyses. A part summary of the SVEP peak amplitude (corrected) analysis is given in Table 4.

In all four analyses the Groups and Disparities factors yielded significant results. The Hemisphere factor, the interactions of Hemisphere *x* Group and Site *x* Group were significant in three analyses, while the

TABLE 3

Means and standard deviations (SD) in microvolts of average peak amplitude (N = 8 trials each subject) of stereoscopic visual evoked potential measured in the latency range 180-310 milliseconds relative to a normalisation period from 10 milliseconds pre-stimulus to 120 milliseconds post-stimulus

Group		Left hemisphere				Right hemisphere			
		O_1		T_5		O_2		T_6	
		E	L	E	L	E	L	E	L
Perceivers	Mean	5.55	4.37	6.60	5.32	5.12	4.15	5.05	3.87
($n = 14$)	SD	2.38	2.17	3.22	2.67	2.56	1.90	2.23	2.20
Non-perceivers	Mean	3.61	2.23	3.78	2.53	3.70	2.84	3.45	2.31
($n = 14$)	SD	1.76	1.79	1.88	1.99	1.34	1.79	1.25	1.46

O_1, O_2, T_5, T_6 = International 10-20 system scalp sites.
E = Edged stimuli; L = Edgeless stimuli.

Hemisphere *x* Site interaction was significant in the main peak amplitude analysis and in the analysis of the N = 32 trial integrals.

Statistical Analysis: Latencies

The latencies of the peak SVEP in the range 180-310 milliseconds were submitted to analysis of variance. Results are not given in detail here (Figure 2). No main effects were significant, but the interactions yielded significant results:

Hemisphere *x* Group, $F = 4.30$, *df* 1/26, $P < 0.05$

Hemisphere *x* Site *x* Group, $F = 5.78$, *df* 1/26, $P < 0.03$

In the N group, in contradistinction to the P group, latencies for the edgeless stimuli were shorter than for the edged stimuli. Mean differences for occipital sites were large in the N group for the two stimulus conditions, especially at O_1 (17.4 milliseconds difference).

TABLE 4

Part Anova Summary of Peak SVEP Amplitude (corrected) data, ordinate measures: Groups [G] *x* Disparity [D] *x* Hemisphere [H] *x* Site [S] *x* *Ss*

Source	df	Mean square	F	P
G (Perceivers, Non-perceivers)	1	84786.45	9.54	0.0047
Error	26	8889.66		
D (Edged, Edgeless)	1	29716.07	9.21	0.0054
DG	1	0.88	0.00	—
Error	26	3227.95		
H (Left, Right)	1	4183.14	8.67	0.0067
HG	1	4921.88	10.20	0.0037
Error	26	482.54		
DH	1	283.50	0.76	—
DHG	1	42.88	0.11	—
Error	26	374.11		
S (Occipital, Temporal)	1	604.57	1.00	—
SG	1	1311.45	2.17	—
Error	26	604.55		
DS	1	68.64	0.31	—
DSG	1	5.16	0.02	—
Error	26	222.29		
HS	1	4500.07	18.40	0.0002
HSG	1	407.16	1.66	—
Error	26	244.64		
DHS	1	103.14	0.72	—
DHSG	1	24.45	0.17	—
Error	26	142.70		

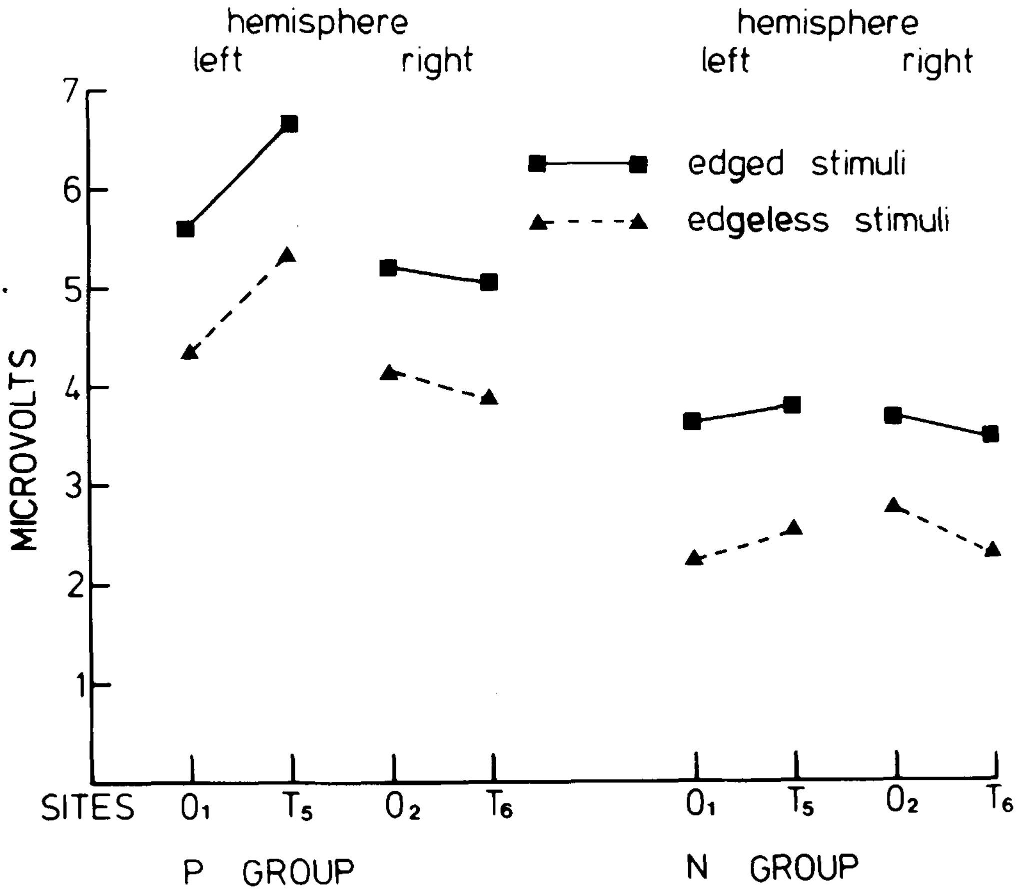

Figure 2: Means of peak SVEP amplitudes in the latency range 180-310 milliseconds.

DISCUSSION

Edged stimuli produced SVEP of greater magnitude than the nebulous stimuli, as predicted. The latter stimuli nevertheless evoked peak responses which exceeded three microvolts in 10 of the P group subjects and six of the N group. Figure 1 shows well developed responses in the P group superaverages to the edgeless stimuli, grading down to poorly developed potentials in the N group. This loss of definition in the N group is largely the result of compounding the waveforms of poor responders with the others. In about one-third of the subjects the SVEP was of higher amplitude to the edgeless than to the edged stimuli. The detail of stimulus-response relationships is a matter for separate report based on wider data. On balance the results of the present study are interpreted to show that, while boundary features exhance the SVEP of about two-thirds of the subjects, these features are inessential to the evocation of the brain response. The evidence suggests that, when random-dot stereoscopic stimuli are presented briefly in the centre field, both the disparity as such and the boundary features contribute to the stereoptic evoked potential.

The groups in this study were formed on the basis of ability to report and describe the stimuli. The results show a clear superiority in SVEP magnitude of the P group over the N group for both classes of stimuli. The second hypothesis is thus also supported. This outcome in itself does not clarify the nature of the perceptive ability. The fact that a strong SVEP was obtained to the distinct stimulus in at least 10 of the 14 subjects of the N group testifies to the

objectivity of the combined random-dot electrophysiological technique. More intensive examination of the stimulus parameters is required to throw light on the perceptive problem.

The latency analysis results may also have some bearing on the problem. The significant Group *x* Hemisphere effect results from longer latencies in the right than the left hemispheres of the non-perceiver group. *Post hoc* analysis of the significant second-order interaction shows, however, that it is the differential in brain response between the occipital and temporal electrodes which is responsible for the Anova results. The mean difference in latency at 0_1 to the edged and edgeless stimuli is 17.4 milliseconds, the response to the *edgeless* stimulus being faster ($t = 3.36$, df 13, $P < 0.01$). In this group the mean latency of the SVEP peak is shorter for the edgeless stimulus at all sites. This is in complete contrast to the picture in the P group where the response to the edged stimulus is faster at all sites. The latency data for O_1 and the group contrast in latencies for the two types of stimulus may have some relevance to the efficiency of stereoscopic perception.

Responses are larger in the left hemisphere overall, but especially in the more efficient stereo group (P group) and outstandingly in this group at the T_5 site. These results are reproduced within the P group on different data and on different dependent measures of amplitude. Herpers *et al.*,[3] using a different system, bipolar recording and a somewhat different technique, reported indications of hemispheric asymmetry in stereoptic evoked responses and raised doubts about the occipital region as the generator of these responses. Our results again give indications of an asymmetry and certainly raise questions which are difficult to answer in terms of the conventionally understood anatomy of the visual systems of the brain. They are, however, group results and need further validation as well as comparison with results obtained in parametric and topographic studies of individual subjects which are to be reported.

ACKNOWLEDGEMENTS

This study was funded by a National Health and Medical Research Council grant, Project No. 80/4265. We thank Anne Quayle, the electrophysiological technician, for her assistance, Wendy Mead for typing, Paul Smith for illustrations and photography, and Mark Manning for computing assistance.

References

1. Regan D. Evoked potentials in psychology, sensory physiology and clinical medicine. London: Chapman and Hall, 1972: 52.
2. Regan D. *Op. cit.*: 57.
3. Herpers MJ, Caberg HB, Mol JF. Human cerebral potentials evoked by moving dynamic random dot stereograms. Electroencephalogr Clin Neurophysiol 1981; 52: 50-56.
4. Neill RA, Fenelon B, Dunlop DB, Dunlop P. The visual evoked response and stereopsis. Aust Orthoptic J 1982; 19: 25-29.
5. Neill RA. Kennewell JA. A clinical test for stereopsis. Australas Phys Sci Med 1979; 2 (8): 463-480.
6. Neill RA. Fenelon B. The objective evaluation of stereopsis. Australas Physics Eng Sci Med 1981; 4 (4): 122-125.
7. Neill RA, Dunlop P, Dunlop DB. Free space stereotests revisited. Aust Orthoptic J 1981; 18: 45-48.